THE EARTHWORMS OF OHIO

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DISSERTATION

Presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Graduate School of the Ohio State University.

BY

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OHIO BIOLOGICAL SURVEY

THE EARTHWORMS OF OHIO

WITH A STUDY OF THEIR DISTRIBUTION IN RELATION TO THE HYDROGEN-ION CONCENTRATION, MOISTURE, AND ORGANIC CONTENT OF THE SOIL

By HENRY W. OLSON

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EARTHWORMS OF OHIO

By Henry W. Olson

INTRODUCTION

Earthworms are among the most common and the best known of our animal forms. Besides occurring almost everywhere in all sorts of soils, some species are found in lakes, streams, and swamps. The fact that they are popularly known by a variety of names—earthworm, angleworm, fishworm, dew-worm, night-crawler, etc.—is evidence of their abundance and wide distribution, as well as, to some extent, their utility.

Almost every lad knows where, when, and how earthworms may be found, and is quite familiar with collecting them with a flash light in the night, as well as with the best places to dig them. To the angler they are important as bait, to such an extent, in fact, that there is a considerable industry in collecting and selling them for this purpose. Because the natural history of the earthworm is but little known to the average reader, it is commonly regarded as a useless and uninteresting animal, which may occasionally serve for bait, or furnish amusement for youngsters. However, they play an important rôle in the teaching of zoology, so that there is no beginning course in this subject which is considered complete without the study of the earthworm to illustrate certain principles of organization, reaction, and adaptation to the mode of life. In research they have been used quite extensively for reaction studies, embryology, histology, regeneration, etc. To the systematist they represent some interesting problems, and many species have been described from various parts of the world. To the ecologist, they furnish interesting studies of distribution.

The economic value of the earthworm is still somewhat uncertain, although it has been shown by Darwin, 1882 *(The Formation of Vegetable Mould)*, that they play a very important part in working over the soil. He showed that they prepare the soil in excellent manner for the growth of fibrous-rooted plants and for seedlings of all kinds. They also periodically expose the organic matter of the soil to the air, and sift it so that no stones larger than the particles which they can swallow are left in the material brought up to the surface. They mingle the whole intimately together, like a gardener who prepares his soil for his choicest plants. In this state the soil is well fitted to retain moisture and to absorb all soluble substances, as well as for the process of nitrification.

Earthworms have been known to burrow to a depth of four to six feet in an almost perpendicular direction. This we can see would naturally aid in draining the soil. These burrows also allow the air to penetrate deeply into the ground, and greatly facilitate the passing of roots to a greater depth. Many seeds owe their germination to the fact that they were covered by the castings of the earthworm. It sometimes happens, too, that they attack the young plants in the gardens and uproot them for food when other things are scarce, so it is possible for them to be a pest. On golf greens thousands of dollars have been spent to get rid of them, as they make the surface uneven with piles of castings from their burrows.

The earthworms, with certain aquatic forms, are included among the segmented bristle-bearing worms termed Annelida or Annulata, and, more narrowly, in that group which has a small number of bristles, the Oligochaeta. The anatomical variations of the Oligochaetous worms are interesting features, but through outward appearance only one may without difficulty distinguish a large number of forms. To the expert it is possible in many cases to go no farther than the external characters before assigning the species to its correct classification.

The wide distribution of the Oligochaeta, which are incapable of active migration on their own account, is believed to be partly explained by their transference, in case of smaller species, as adults, or as eggs in the mud which clings to the feet of birds. The cocoons of the Oligochaeta seem in many cases suitable for carriage in this fashion, more especially those of the aquatic Oligochaeta, which deposit their eggs in situations frequented by wading birds. The small size of the cocoon no doubt plays an important part in making it more suitable for carriage. With earthworms the case is rather different, for the cocoons are usually buried in the ground. Michaelsen and Beddard have shown that many of the Oligochaeta have cocoons from which a great many embryos emerge. One can readily see that the transference of a single cocoon might be sufficient to supply a new territory. Among the earthworms the number of embryos that reach maturity in a single cocoon is very limited. Beddard in his Monograph of the Order of Oligochaeta states that the species of Allolobophora and Lumbricus are widely distributed and "that their wide range might possibly be accounted for by human agency." It seems to be the opinion of helminthologists that most of the species of Lumbricidae found in North America were originally European and have accidentally been introduced into this continent.

The literature on the North American Lumbricidae is decidedly small. Such workers as Michaelsen, Stephensen, Eisen, Vaillant, Vejdovsky, Moore, Benham, Beddard, and Smith are chiefly responsible for the literature on this group. Smith (1917) is, to my knowledge, the only one who has ever published a systematic list of species found in North America. No systematic study of the earthworms of Ohio has ever been published.

It is a pleasure to acknowledge the help and the stimulating interest of Dr. Raymond C. Osburn, Dr. William M. Barrows, and other members of the Zoology Department of Ohio State University. I also wish to thank various individuals of the Soils Department of The Ohio State University for the use of apparatus and for assistance in determining various soil samples collected throughout the State. The Graduate School of The Ohio State University contributed to this work by paying for certain chemical determinations.

BREEDING HABITS OF THE EARTHWORM

The clitellum plays an important part during the breeding of the earthworm and is present in all terrestrial Oligochaeta. Some of the other families do not possess a clitellum, and the absence of this organ has been frequently used as a mark of specific distinction. Some inaccurate descriptions were made with reference to the clitellum by earlier writers, but later it was found that the clitellum was really present in fully mature worms. We can undoubtedly say that a clitellum exists in all the Oligochaeta, especially during the period of sexual maturity. The presence of the clitellum indicates the breeding period; its function is that of producing the cocoon and when that function has ceased the clitellum disappears. The period of its existence differs in various species. The clitellum is made up of modified epidermis. The muscular layer has undergone considerable diminution. In most cases, though, the clitellum stands out above the body surface. The color, as a rule, is quite different from the rest of the body. The number of segments which the clitellum covers varies with the species.

Earthworms breed most actively from June to October, or even later in the season, providing the eggs are laid in a shady and damp place, and at a considerable depth. Each individual is a male-female (hermaphrodite), so anyone of the same species will do for a mate. Though having both eggs and spermatozoa, they are not self-fertilizing, but mutually fertilize each other's eggs. The whole process of fertilization and cocoon formation is somewhat elaborate.

The two worms meet and overlap one another for about one-

third to one-fourth of their lengths, with the heads facing in opposite directions and the ventral sides in contact. They then secrete quantities of viscous mucus, which forms a thick band about the clitellar regions of their bodies. These mucous bands surround both bodies and serve to bind the copulating individuals tightly together. Each worm then acts as a male, giving off a quantity of seminal fluid that is conducted along the grooves to the seminal receptacles of the other, where it is picked up and stored. After the worms have separated, the slime tube which is formed by the clitellum of the worm is worked forward over the body, collecting albumen from the glands of the ventral side. As it passes over the fourteenth segment, it collects a few eggs from the oviducts; and then passes the ninth and tenth segments, where it receives spermatozoa from the seminal receptacles where they have been stored up. The sperm then fertilizes the eggs. The slime tube is gradually slipped off over the head, closing up as though with a draw-string as first its anterior end and then its posterior end slips off over the sharp prostomium. This closed slime tube, with the fertilized eggs and nutritive fluid which it contains, constitutes the cocoon. In this cocoon the eggs develop directly into the young worms, which, when ready to emerge, crawl out through one end of the cocoon after the slime plug has been dissolved away. The cocoons vary in size and shape according to the species. The smallest are hardly one millimeter in length, while the largest are as large as eight millimeters. The shape of the capsules of *Helodrilus trapezoides* is oval, with the ends pointed, or sometimes slightly depressed; such a depression corresponding to the primitive ventral opening of the chitinous ring formed by the clitellum, which does not close until after deposition. Their color resembles that of corn. In *Lumbricus terrestris* the capsules are lemon shaped, having an olive color. The number of eggs in the capsules of *H. trapezoides* is from three to eight, in those of *L. terrestris* it is from four to twenty. All of the eggs of *L. terrestris* become fecundated and develop; on the other hand, in the capsules of *H. trapezoides,* one egg only, or rarely two or three produce embryos. The other eggs, not undergoing fertilization, lose their spherical form and become transformed into flat plates with more or less irregular outlines. The protoplasm, by a kind of coagulation, changes into a dark substance containing granules, and the unfertilized eggs gradually dissolve and vanish without leaving a trace.

Cleavage and the formation of the germ layers in the Oligochaeta have been thoroughly studied by various investigators

(Kowalevsky, Hatschek, Kleinenberg, Wilson, Vejdovsky). In *Lumbricus* a blastula is formed which is thicker on one side and which may be flattened so that the cleavage cavity is small; and the gastrula, which soon arises by invagination, is also at first rather flat (Kowalevsky). These characteristics are less marked in the case of *Helodrilus trapezoides,* in which occurs the peculiar phenomenon of the division of the embryo in the gastrula stage so as to produce two embryos, which, separated from each other, develop further. The embryos escape as small worms in about two or three weeks.

ACTIVITIES OF EARTHWORMS

Earthworms are expert tunnelers. They literally eat their way through the soil, which is swallowed and is then passed through along the alimentary tract where it is put through a digestive process and its nutritive materials removed. The residue is deposited in the form of castings near the mouth of the burrow. Charles Darwin, who made a detailed study *(The Formation of Vegetable Mould)* of the role of the earthworm as an agricultural agent, discovered that an enormous amount of new earth is brought up to the surface and exposed to the action of the air by the worms. He estimated that about eighteen tons per year for each acre of land were brought up in certain regions. Surface rock and historical remains of buildings have been gradually buried by the castings, and the ground opened up by numerous tunnels and thus made more available for agriculture. E .J. Salisbury made a detailed study of the worm casts of the earthworms. He concluded that the worm casts, as compared with the soil from which they are derived, are usually acid (or less alkaline), the change amounting in some cases to as much as 75 per cent of one point pH. The worm casts commonly contain a higher proportion of carbonates than the surface soil, and the frequency of earthworms in natural soils appears to be greatest in those which are approximately neutral in reaction, and to diminish as the acidity or the alkalinity increases. Earthworms may thus have a marked degree of effect on the vegetation and retard the edaphic succession.

Earthworms are chiefly nocturnal animals. During the day they lie quietly in their burrows with the head end near the surface. At night they become very active, crawling partially out of their burrows and foraging about for food. The tail end is usually left in the burrow as an anchor, so that in case of danger a quick retreat for shelter may be made. The anchorage of their tail end aids them in uprooting small plants; the anterior end is coiled

around the basal part of the stem, and with the contraction of their longitudinal muscles, the uprooting of the plant is completed. Earthworms have been seen to uproot young onions in this way. Apart from organic matter in the soil the chief food of earthworms consists of leaves, as well as the previously mentioned plants. Hoffmeister *(Familie der Regenwürmer)* and Darwin *(The Formation of Vegetable Mould)* have shown that they will also eat meat. I have found that they care for fresh and not putrid meat. Young cabbage plants are also taken to their burrows and used for food. They pour upon the food substance to be eaten a sort of salivary fluid which softens the material and partly digests it. The fluid in which the leaf is bathed acts upon the fresh leaf in a remarkable manner, discoloring it. The soft parts are sucked off and swallowed, leaving the veins of the leaf looking like fine lace. Cabbage leaves upon which earthworms have crawled will be marked in sinuous lines; the cells in that portion lose their green coloring matter (chlorophyll), and the starch granules are digested. During the night they frequently take leaves into their burrows, with which they line the enlarged chamber at the bottom. Frequently small pebbles are taken into the burrow to line it.

In moving about in the burrow the worm makes use of its muscular system and setae (bristles). The number of setae and their position on the body varies with the species. In moving forward, the procedure is as follows: the posterior setae are thrust out and take hold, thus anchoring the body at the rear; the circular muscles of the rest of the body contract making the animal longer and narrower, causing the anterior portion to advance. When fully extended, the setae of the anterior end are thrust out and that end is anchored; the posterior setae are withdrawn, and the body shortens by contracting the longitudinal muscles, thus bringing the posterior end forward. This series of operations is repeated so long as the worm travels.

DEFINITION OF TERMS USED IN IDENTIFICATION

Smith (17) has published a definite system of terms and symbols, and his statement with some modification will be adopted for use for this paper.

The limits of the somites externally are indicated by the intersegmental grooves between the segments, while internally the septa or partitions serve this purpose. The somites are numbered from the anterior end, not counting the prostomium, which is not a segment. Each somite is designated by arabic numerals. Should the

first inter-segmental groove be obscure, one can distinguish the second somite, since it is the first to bear setae. The inter-segmental grooves for any two adjacent somites are represented by a formula; 5/6 indicates the groove between segments 5 and 6.

In the Lumbricidae there are eight setae to a somite, and these are usually arranged in pairs, two pairs on a side. They may be closely or widely paired, or separate. The setae on either side are

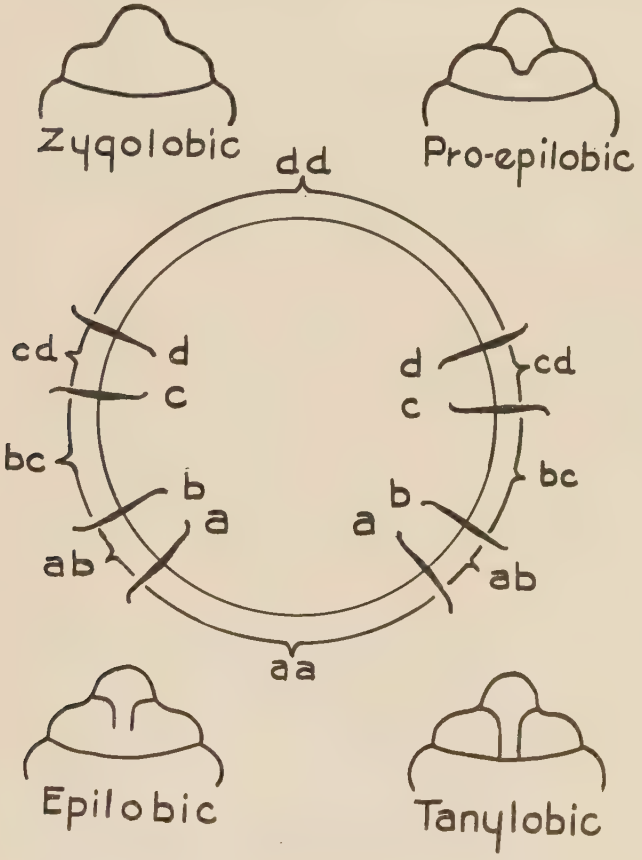


FIGURE I.

indicated by the use of letters, a, b, c, and d. The ventral-most seta is designated by a, the next by b, the next c, and the dorsal-most by the letter d. Should the distance from a to b and from c to d be less than one-third of the distance between b and c, the setae are said to be closely paired. (Figure 1.)

If the prostomium divides the peristomium completely and the longitudinal grooves which form its lateral boundaries extend

clear to the inter-segmental groove 1/2, the prostomium is said to be tanylobic. Should the prostomium and its lateral grooves extend only part way across the peristomium and fail to reach the groove 1/2, it is said to be epilobic. When the prostomium and the peristomium are entirely fused or coalesced, it is said to be zygolobic (Sparganophilus). (Figure 1.)

On some of the somites of the clitellum, along the ventral edges, there are glandular ridges termed tubercula pubertatis. They may vary as to their position in the clitellular region, and in some cases they may be absent. The spermathecae are pouches which open to the exterior and receive the sperm cells from another individual. They vary as to position, and in some species they are totally absent. The oviducal pores are on somite 14 in the Lumbricidae. The spermiducal pores are usually on somite 15, but in some of the Lumbricidae they are present on the 13th somite.

Family LUMBRICIDAE

This family has eight setae to a somite. The anterior border of the clitellum is posterior to the spermiducal pores which in most cases are on somite 15 but in a few are from one to three somites further anterior. The calciferous gland is situated in the region of the gonads. A gizzard is present at the anterior end of the intestine. There are no typical prostate glands extending free into the coelomic cavity. The spermaries and spermiducal funnels are in 10 and 11. The ovaries are in 13. The oviducal pores are in 14.

HISTORICAL

The genus Lumbricus and the old genus Allolobophora are practically the only important terrestrial genera of Oligochaetous worms prevalent in Europe and North America. Michaelsen (1910), in a discussion and revision of the various genera under the Lumbricidae, reduces the genera to three. They are Helodrilus, Lumbricus, and Octolasium. They are widely distributed in all parts of the world except in the tropics, and are especially abundant in the United States. Smith and Gittins (1915), listed 19 species for the state of Illinois.

KEY TO THE OHIO SPECIES OF LUMBRICIDAE

1. (32)	Prostomium incompletely divides the peristomium, epilobic..	2
2. (31)	(Spermaries and the spermiducal funnels not inclosed in sperm vesicles). Anterior margin of the clitellum is anterior to 30 in the species included in this key....*Helodrilus*	3
3. (11)	Spermathecal pores, dorsal setae, near mid-dorsal line.....	4
4. (7)	Posterior margin of the clitellum not extending as far as 29; anterior dorsal surface of the body pigmented with some	

shade of brown. Amphibious.....Subgenus *Eiseniella* 5

5. (6) Spermiducal pores on 13; clitellum on 22 or 23-26 or 27 .....*H. (E.) tetraedrus typica*

6. (5) Spermiducal pores on 15; clitellum on 22 or 23-27..... .....*H. (E.) tetraedrus hercynia*

7. (4) Clitellum extending posteriorly at least to 29..... .....*Subgenus Eisenia* 8

8. Setae closely paired; two pairs of spermiducal pores..... 9

9. (10) Clitellum on 24, 25 or 26-32; transversely banded with brown and buff.....*H. (E.) foetidus*

10. (9) Clitellum on 24, 25 or 26-31, 32 or 33; tubercula pubertatis 29-31; without pigment.....*H. (E.) roseus*

11. (3) Spermiducal pores, when present, in or ventral to setae line d..... 12

12. (16) (18) Four pairs of sperm sacs in 9-12; spermathecae present; setae closely paired.....Subgenus *Allolobophora* 13

13. (14) (15) Clitellum, 27 or 28-34 or 35; tubercula pubertatis, 31 and 33 .....*H. (A.) caliginosus typica*

14. (13) (15) Clitellum, 27 or 28-34 or 35; tubercula pubertatis, 31-33.. .....*H. (A) caliginosus trapezoides*

15. (13) (14) Clitellum, 29-37; tubercula pubertatis on 31, 33 and 35.. .....*H. (A.) chloroticus*

16. (12) (18) Three pairs of sperm sacs in 9, 11, and 12; spermathecae present; setae of North American species widely apart or separate.....Subgenus *Dendrobaena* 17

17. Clitellum on 25 or 26-31 or 32; tubercula pubertatis, 28-30.. ..... *H. (D.) subrubicundus*

18. (12) (16) Two pairs of sperm sacs in 11 and 12; spermathecae absent (sometimes imperfectly developed in *H. tenuis*)..... .....*Subgenus Bimastus* 19

19. (30) Setae more or less closely paired..... 20

20. (29) Clitellum including less than 10 somites..... 21

21. (22) Anterior margin of clitellum, anterior to 23..... 22

22. (23) Clitellum on 22-29; ab equal to cd.....*H. (B.) tumidus*

23. (22) Clitellum beginning at 20-22; ab greater than cd..... .....*H. (B.) gieseleri* and var *hempeli*

24. (21) Anterior margin of clitellum on 24 or 25..... 25

25. (26) Clitellum, 24-30.....*H. (B.) parvus*

26. (25) Clitellum, 24 or 25-31.....*H. (B.) beddardi*

27. (20) Clitellum including 10 somites or more..... 28

28. (29) Clitellum, 23-32 or 24-33.....*H. (B.) longicinctus*

29. (28) Clitellum, 27-37.....*H. (B.) zeteki*

30. (19) Setae widely paired; clitellum, 26-31 or 32....*H. (B.) tenuis*

31. (2) (Spermaries and spermiducal funnels inclosed in sperm vesicles.) Clitellum 30-35; tubercula pubertatis, 31-34; setae separate or widely paired.....*Octolasium lacteum*

32. (1) Prostomium completely divides the peristomium—tanylobic; spermaries and spermiducal funnels inclosed in sperm vesicles; sperm sacs in 9, 11, and 12.....*Lumbricus* 33

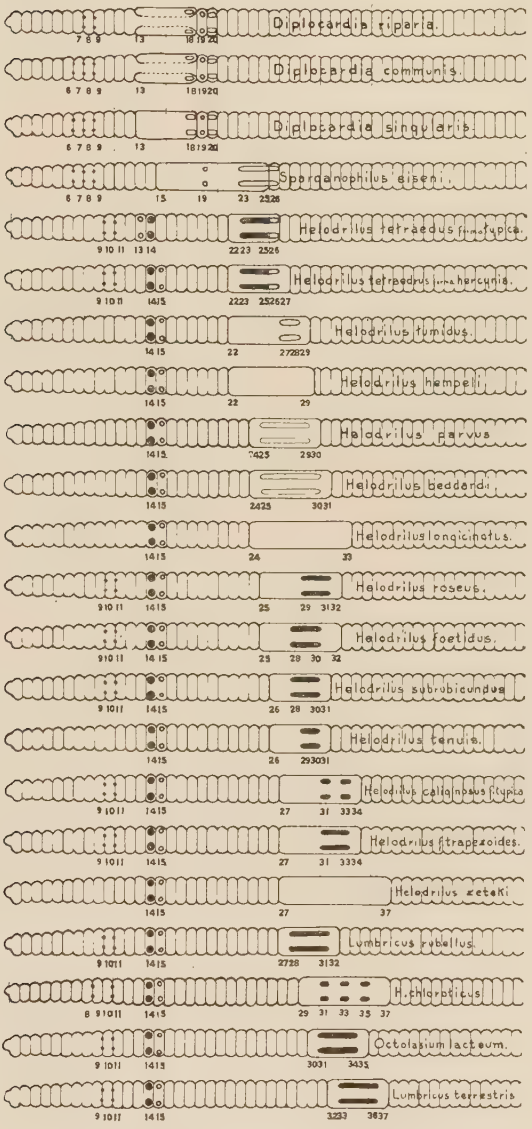
33. (34) Clitellum, 26 or 27-32; tubercula pubertatis 28-31..*L. rubellus*

34. (33) Clitellum, 31 or 32-37; tubercula pubertatis, 33-36 *L. terrestris*

Tabular Key

Clitellum	Tubercula pubertatis	Prostate pores	Spermiducal pores	Spermathecal pores	Sperm sacs	Setae	No. of Somites	length cm.	Color (antero-dorsal)	Name
XIII XVIII, Saddle	-- - ... -- ----	XVIII, XX	XIX	VII/VIII, VIII/IX	IX, XII	Wide	135-160	20-27	Brown	Diplocardia riparia
XIII XVIII, Saddle	-------- -----	XVIII, XX	XIX	VII/VII, VII/VIII, VIII/IX	IX, XII	Wide	125-160	18-30	Pale	Diplocardia communis
XIII XVIII, Cinqulum	----------	XVIII, XX	XIX	VII/VII, VII/VIII, VIII/IX	IX, XII	Wide	90-120	4-12	Pale	Diplocardia sinqularis
XV-XXV	---- -------	XXIII-XXVI	XIX	VII/VII, VII/VIII, VIII/IX	XI, XII	Close	165-225	15-20	Pink with blue iridescence	Sparqanophilus eiseni
XXII, XXIII-XXVI, XXVII	XXIII-XXV, XXVI	----------	XIII	IX/X, X/XI, dorsal	IX-XII	Close	80-100	4-6	Brown	Helodrilus tetraedrus f. typica
XXII, XXIII-XXVII	XXIII-XXV, XXVI	----------	XV	IX/X, X/XI, dorsal	IX-XII	Close	80-100	4-6	Brown	H. tetraedrus f. hercynius
XXII-XXIX	XXVII, XXVIII	-- -	XV	None	XI, XII	Close	40-60	2-5	Reddish-brown	H. tumidus
XXII-XXIX or XXX	None	--------	XV	None	XI, XII	Close	100-110	4-7	Brown-red	H. qieseleri var. hempeli
XXIV-XXX	XXV, XXVI-XXIX, XXX (indefinite)	--------	XV	None	XI, XII	Close	90-110	3-4	Brown-red	H. parvus
XXIV, XXV-XXXI, XXIII	XXIV, XXV-XXX (indefinite)	--------	XV	None	XI, XII	Close	70-100	2-6	Reddish-brown	H. beddardi
XXIII, XXIV-XXXIII	None	--------	XV	None	XI, XII	Close	100-130	7-10	Rose-red	H. longicinctus
XXIV, XXV, XXVI-XXXI, XXXIII or XXXIII	XXIX, XXX-XXXI	----------	XV	IX/X, X/XI	IX-XII	Close	130-150	4-8	Pale-red	H. roseus
XXIV, XXV or XXVI-XXXII	XXVIII-XXX, XXXI	----------	XV	IX/X, X/XI	IX-XII	Close	75-125	5-15	Brown and buff (bands)	H. foetidus
XXV, XXVI-XXXI, XXXII	XXVIII-XXX	----------	XV	IX/X, X/XI	IX, XI, XII	Wide	80-125	5-8	Red	H. subrubicundus
XXVI-XXXI	XXIX, XXX (indistinct)	--------	XV	None	XI, XII	Wide	90-110	4-8	Red	H. tenuis
XXVII-XXXIV, XXXV	XXXI, XXXIII	--------	XV	IX/X, X/XI	IX-XII	Close	100-250	5-20	Rose-red	H. caliginosus f. typica
XXVII-XXXIV, XXXV	XXXI-XXXIII	--------	XV	IX/X, X/XI	IX-XII	Close	100-250	5-20	Rose-red	H. f. trapezoides
XXVII-XXXVII	None	--------	XV	None	XI, XII	Close	110-140	10-12	Chestnut-brown (purplish)	H. zeteki
XXVII-XXXII	XXVIII-XXXI	----------	XV	IX/X, X/XI	IX, XI, XII	Close	90-115	7-13	Reddish-brown (violet)	Lumbricus rubellus
XXIX-XXXVII	XXXI, XXXIII, XXXV	----------	XV	VIII/IX-X/XI	IX-XII	Close	80-125	5-7	Greenish	H. chloroticus
XXX-XXXV	XXXI-XXXIV	--------	XV	IX/X, X/XI	IX-XII	Wide	100-170	5-16	Pale-pink	Octolasium lacteum
XXXI, XXXII-XXXVII	XXXIII-XXXVI	----------	XV	IX/X, X/XI	IX, XI, XII	Close	125-175	15-25	Brown—violet	Lumbricus terrestris

DIAGRAMMATIC KEY TO OHIO EARTHWORMS



Explanation of Plate.

- Prostate pores.
- Tubercula pubertatis (⟺ Indefinite ▬ Present).
- Oviducal pores.
- Spermiducal pores.
- Spermathecae pores.

H.W. Olson.

FIGURE 2.

Genus **Lumbricus** Linnaeus (1758) amended by Eisen (1874)

Prostomium completely divides the peristomium, and the longitudinal grooves which form its lateral boundaries extend to the intersegmental groove ½ (tanylobic). The spermaries and the spermiducal funnels are inclosed in the sperm vesicles. The sperm sacs are in 9, 10, and 12. The setae are closely paired posterior to the clitellum.

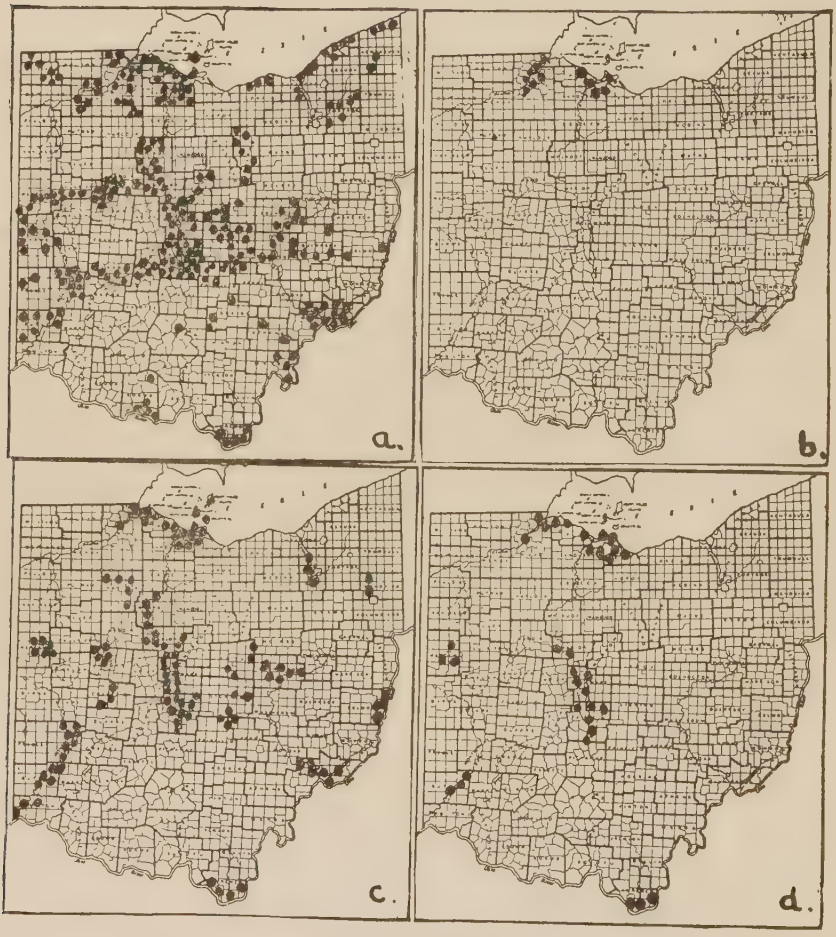


FIGURE 3.

Fig. 3—a Lumbricus terrestris b Lumbricus rubellus
c Helodrilus tetraedrus f. typica d Helodrilus tetraedrus f. hercynia

Lumbricus terrestris Linnaeus (1758), Müller (1774)

Lumbricus terrestris Linnaeus, (part) 1758; 674.
Lumbricus americanus Perrier, 1872:44.

Length 15 to 25 cm. Somites 125 to 175. The color of the anterior dorsal

surface is brownish blue, reflecting a prominent greenish violet color. The clitellum covers somites 32 to 37. Smith states that the clitellum may begin on somite 31. I have found this to be true for my Ohio specimens. Tubercula pubertatis on 33 to 36. Prostomium, tanylobic. Setae closely paired; posterior to the clitellum, aa:ab:bc:cd = 4:1:3½: ¾:16. First dorsal pore on 7/8. Oviducal pore on 14, slightly dorsal of b. Spermiducal pores on 15, between b and c. Spermathecal pores on 9/10 and 10/11, in line with cd. Spermathecae in 9 and 10. Sperm sacs in 9, 10 and 11. Longitudinal partitions of the calciferous gland, 70-75 in number. Septa 6/7 — 9/10, strongly, and 10/11 — 14/15, moderately, thickened.

This species is widely distributed in Europe and has been reported in North America, from Massachusetts, Illinois, New York, Maine, Connecticut, Maryland, District of Columbia, Michigan, Colorado, California, and Ohio.

In Ohio they have been collected in these counties: Washington, Athens, Meigs, Hocking, Fairfield, Perry, Ross, Franklin, Licking, Delaware, Knox, Butler, Preble, Darke, Mercer, Logan, Montgomery, Adams, Clark, Madison, Auglaize, Morrow, Wyandot, Marion, Hardin, Hancock, Wood, Sandusky, Ottawa, Lucas, Henry, Williams, Muskingum, Coshocton, Guernsey, Belmont, Lorain, Cuyahoga, Ashtabula, Lake, Summit, Portage, and Ashland. (Figure 3). This species has become widely distributed over Ohio in the last ten years. I have made collections in all parts of the state and have not once failed to find them. They are abundant in the central part of the state; in fact, so abundant that one finds the gutters of the streets and sidewalks full of them after a rain in the springtime. I have collected this species in almost all seasons of the year. They have been found after a warm snow, showing that they are quite active at a low temperature.

Lumbricus rubellus Hoffmeister

Lumbricus rubellus Hoffmeister, 1843:187

Length 7-13 cm. Somites, 90-145. Color, reddish brown or deep violet; color more pronounced on the anterior dorsal surface. Clitellum covers somites 27-32; Smith states that it exceptionally begins on 26. None of my specimens show this condition. Tubercula pubertatis on 28-31. The prostomium is tanylobic. Setae are closely paired; aa:ab:bc:dd = 5:1:5: 5/6:19. The oviducal pore is on somite 14, slightly dorsal of b. Spermiducal pores on 15. Spermathecal pores on 9/10 and 10/11, in line with cd. Sperm sacs in 9, 11, and 12. There are about 60 longitudinal partitions of the calciferous gland. Septa 6/7 — 8/9, somewhat thickened; others but very little, with the exception of those in region of the sperm sacs. Spermathecae are in 9 and 10.

This species is usually collected among debris. It is widely distributed in Europe and Siberia and in North America has been reported for Newfoundland, California, Oregon, Washington, Michigan. It has been collected in the following counties: Wood, Lucas, Ottawa, and Sandusky but has never been listed for Ohio heretofore (Fig. 3).

Genus **Helodrilus** Hoffmeister, 1845

The species of this genus are distinguished by the absence of special sperm vesicles enclosing the spermaries and spermiducal funnels.

The following are subgenera for North America: Eiseniella, Eisenia, Allolobophora, Dendrobaena, Bimastus. A description of each of these will be given under each subgeneric heading.

Subgenus **Eiseniella** Michaelsen, 1900

Michaelsen's Oligochaeta in *Das Tierreich* considers Eiseniella a genus. This group was later reduced to sub-generic rank by Michaelsen in 1910 where he considers Eiseniella very closely related to the sub-genus Eisenia. So closely related are they that the only character used as a basis for their separation is the somewhat shorter gizzard which is chiefly restricted to the 17th somite in Eiseniella and ordinarily involves, in addition, more of the 18th somite in others. The position of the oviducal pores is also a significant character. Smith states that the American material of *Helodrilus tetraedrus, H.t.hercynia,* and Eisen's *Tetragonurus pupa* has shown that in every specimen examined the oviducal pores open slightly mesad of a, instead of slightly dorsal of b, as they do in all other Lumbricidae. Eiseniella differs from all the other subgenera, except Eisenia, in having the pores of the paired spermathecae between the seta line d and the mid-dorsal line.

Helodrilus (Eiseniella) **tetraedrus** (Savigny) 1826, forma **typica**, Michaelsen

Enterion tetraedrum Savigny, 1826:184.
Allurus tetraedrus Eisen 1874:54.
Eiseniella tetraedra (typica) Michaelsen, 1900a:471.
Helodrilus (Eiseniella) *tetraedrus forma typica,* Michaelsen, 1900:11.

Length of Ohio specimens 4-6 cm. Somites 80-100. Color usually some variable shade of brown. Prostomium epilobic. Setae paired; aa:ab:bc:cd:dd =3:1:3:1:6, slightly posterior of the clitellum; near the posterior end, aa:ab:bc:cd:dd = 5:2:5:2:6-8. Clitellum situated on somites 22 or 23-26 or 27. Tubercula pubertatis on 23-25, seldom on 26. First dorsal pore is on 4/5. Spermiducal pores on 13. Oviducal pores on the 14th somite, usually situated mesad of a, the spermathecal pores on 9/10 and 10/11 between d and the mid-

dorsal line. Septa, 7/8-11/12 are slightly thickened. The calciferous gland is very poorly developed compared to other Lumbricidae and the longitudinal partitions are narrow. Sperm sacs in 9-12. Spermathecae are on the dorsal side chiefly in septa 9/10 and 10/11.

Helodrilus tetraedrus forma typica is usually found in the water-soaked banks of streams, lakes, and ponds. It has been collected in Europe and in many parts of the world where Europeans have settled. In the United States it has been reported for Pennsylvania, California, Michigan, Indiana, Illinois, Colorado, Washington (Puget Sound region), and Ohio.

In Ohio this species has been collected by the writer in the following counties: Lucas, Ottawa, Mercer, Logan, Butler, Montgomery, Washington, Belmont, Hamilton, Franklin, Delaware, Marion, Knox, Fairfield, Licking, Champaign, Hancock, Wyandot, Summit, Coshocton, Mahoning and Lawrence (Fig. 3).

Helodrilus tetraedrus forma **hercynia** (Michaelsen), 1890

Allurus hercynius Michaelsen, 1890:7.
Eiseniella tetraedra Michaelsen, 1900a:473.
Helodrilus (Eiseniella) *tetraedrus f. hercynia* Michaelsen, 1910:11.

This variety is very similar to that of *Helodrilus f. typica* except that the spermiducal pores are on 15 instead of 13.

It has been collected in about the same habitats as *typica* except that in Ohio it has only been taken in the central and southern parts, Lucas, Ottawa, Erie, Butler, Franklin, Delaware, Marion, Lawrence, Washington and Mercer counties (Fig. 3). Smith states that it is very abundant about Urbana, Illinois, and that it is found in association with *typica*. My specimens were almost always found with *typica*. It is new for Ohio.

Subgenus **Eisenia** Malm, 1877

The characters used as a basis for separation of Eiseniella from Eisenia are as follows: shorter gizzard, which is chiefly confined to the 17th somite in Eiseniella, while in Eisenia it ordinarily involves more of the 18th; the location of the spermathecal pores, which are near the mid-dorsal line, slightly dorsal of d. The location of the spermathecal pores are alike in both Eiseniella and Eisenia, and the position of the spermathecal pores alone separates this subgenus from all others except Eiseniella. The oviducal pores open slightly mesad of a, instead of slightly dorsal of b, as in all other subgenera, with the exception of Eiseniella.

Helodrilus (Eisenia) **foetidus** (Savigny), 1826

Enterion fetidum (corr. foetidum) Savigny, 1826:182.
Allolobophora foetida Eisen, 1874:50.
Eisenia foetida Malm, 1887:45.
Helodrilus (Eisenia) *foetidus* Michaelsen, 1910:16.

The length of the specimens collected was 5-15 cm. Smith's measurements are 6-13 cm. Somites 75-125. This worm has a very conspicuous and characteristic coloring, due to transverse purple brownish bands on the middle area of the somites, and alternating with an almost pigmentless intersegmental area. The pigment is also lacking on the lateral area of 9-11. Prostomium epilobic ½. Setae closely paired. Clitellum begins on 24, 25, or 26-32. Tubercula pubertatis on somites 28-30 or 31. First dorsal pore on 4/5. Spermiducal pores on somite 15, between b and c and not close together. Oviducal pores on 14, slightly in a dorsal position from b. Spermathecal pores on 9/10 and 10/11, near the mid-dorsal line. The septa of the anterior somites are not very thick, those of 7/8-9/10, 13/14 and 14/15 are slightly thicker. The sperm sacs are in 9-12. Sperm sacs in 9 and 10 are smaller. The spermathecae are usually in 9 and 10 and are in relation to the septa 9/10 and 10/11. They may be in a position posterior to the septa.

This species is the one generally used for experimental biological work and appears frequently in such literature under the name *Allolobophora foetida.* This use is due to the fact that it can be readily obtained in all seasons of the year, as it finds very favorable conditions in manure, near stagnant pools, and in decayed vegetation, especially where a great deal of moisture is present. Frequently I have found this species with *H. subrubicundus,* as both have a similar soil habitat. I have almost never collected *H. subrubicundus* without finding *H. foetidus* also.

Helodrilus foetidus is widely distributed in the various parts of the world. In North America, where it is very abundant, it has been collected along the Atlantic and Pacific coasts, in the Mississippi Valley, Rocky Mountain region, and the Gulf states (Smith 1917). In Ohio, it is probably found in all counties of the state. Some of the counties in which the writer has collected the species are: Williams, Fulton, Defiance, Henry, Lucas, Wood, Ottawa, Sandusky, Erie, Lorain, Cuyahoga, Lake, Ashtabula, Hancock, Wyandot, Marion, Morrow, Knox, Ashland, Summit, Portage, Mahoning, Jefferson, Belmont, Washington, Meigs, Lawrence, Adams, Hamilton, Butler, Warren, Greene, Preble, Montgomery, Clark, Madison, Franklin, Delaware, Union, Champaign, Logan, Darke, Mercer, Auglaize, Hardin, Pickaway, Ross, Pike, Licking, Fairfield, Hocking, Perry, Athens, Coshocton, Muskingum, Harrison, and Guernsey (Fig. 4).

Helodrilus (Eisenia) **roseus** Savigny, 1826:182

Enterion roseum Savigny, 1862:182.
Allolobophora rosea Rosa, 1893:427.
Eisenia rosea Michaelsen, 1900a:478.
Allolobophora mucosa Eisen, 1874:47.

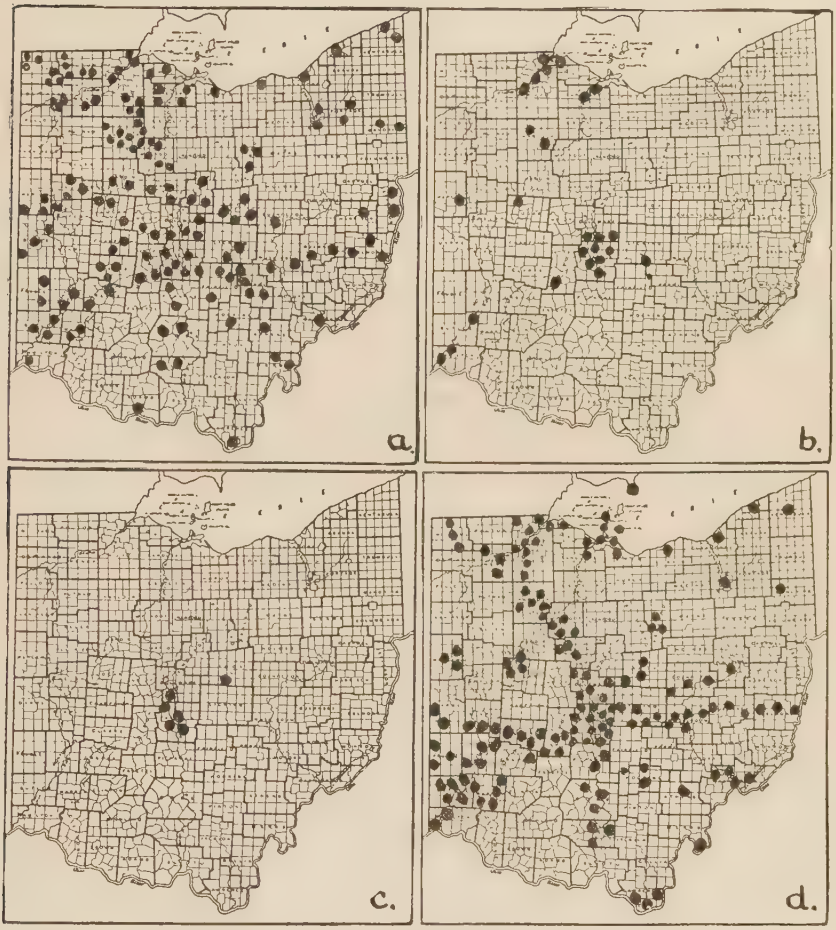


FIGURE 4.

Fig. 4—a Helodrilus foetidus b Helodrilus roseus
c Helodrilus caliginosus f. typica d Helodrilus caliginosus f. trapezoides

Length 4-8 cm. Somites 130-150. Color pale red; the body walls without pigment. Prostomium epilobic ½. Setae closely paired. Clitellum on somites 25-32 and may involve 24 or 33. Tubercula pubertatis usually on 29-31, occasionally 30-31. Glandular papillae may have modified genital setae, often including one or more setal bundles of 9, 10, 12, or 13. First dorsal pore

on 4/5. Spermiducal pores on 15 near b. Oviducal pores on 14, slightly dorsal of b. Spermathecal pores on 9/10 and 10/11 situated near the mid-dorsal line. Septa 6/7-9/10, thickened considerably; others to 14/15, slightly. Sperm sacs in 9-12. The spermathecae are on the dorsal side of 10 and 11 with short ducts.

This species is widely distributed in Europe and in various parts of the world. In the United States it has been reported for New York, Georgia, Indiana, Illinois, Louisiana, Arizona, California and Maine. The writer has collected this species in the following counties: Franklin, Delaware, Butler, Hancock, Wood, Lucas, Madison, Licking, Logan, Mercer, Sandusky, and Hamilton (Fig. 4). This species has never been listed for Ohio heretofore.

Subgenus **Allolobophora** Eisen, 1874

Michaelsen 1900a:480 gives the following description for the subgenus Allolobophora: "The prostomium is usually epilobic, very seldom tanylobic. The setae are more or less closely paired. Spermiducal pores on 15. Spermathecal pores consisting of two or three pairs in the setal line cd. Gizzard including more than one segment. The testes and seminal funnels free; 4 pair of sperm sacs in 9-12. Sperm sacs of 10 as large as those of 9. (always?)."

Smith (1917) adds the following: The setae are more or less closely paired. Sperm sacs, four pairs in 9-12; those of 12 approximately as large as those of 9.

Helodrilus (Allolobophora) **caliginosus** forma **typica,** Savigny, 1826

Enterion caliginosum Savigny, 1862:180.
Allolobophora caliginosa Rosa, 1893:442.
Helodrilus (Allolobophora) *caliginosus* Michaelsen, 1800a:482.

The length of this species is quite variable, 5-20 cm. Somites 100-250. The color of the anterior dorsal surface is a brown-red iridescent color, which is variable in intensity in the different specimens collected. Prostomium epilobic. Setae closely paired, those of the lateral pairs especially. Clitellum situated on somites 27-34 or 35. Tubercula pubertatis on 31 and 33. There are conspicuous glandular papillae which surround the ventral setae 9, 10, and 11 and are usually present on 32-34 and may be absent on 28 and 30. First dorsal pore on 9/10. Spermiducal pores on 15, rather more than half way from b to c. Oviducal pores are on somite 14, slightly dorsal of b. The spermathecal pores on 9/10 and 10/11 are in line with the dorsal bundles. The septa of 6/7-9/10 are very strongly thickened, while those of 5/6 and 11/12-14/15 are less so. The longitudinal partitions of the calciferous gland are about 55-65 in number. The sperm sacs are in somites 9-12. The spermathecae are within the septa of 9/10 and 10/11 and do not extend freely into the somite cavities.

This species is not so abundant in Ohio, and it has been found only occasionally by the writer with *Helodrilus f. trapezoides.* It was found in Franklin, Delaware, and Knox counties (Fig. 4). This species has never been listed for Ohio heretofore.

Helodrilus (Allolobophora) forma **trapezoides** Duges, 1828

Lumbricus trapezoides Duges, 1828:289.
Allolobophora turgida forma tuberculata Eisen, 1874a:43.
Allolobophora turgida Eisen, 1874:46.
Helodrilus (Allolobophora) *caliginosus trapezoides* Michaelsen, 1900a:483.

This variety differs from *f. caliginosus* only in the position of the tubercula pubertatis. In *typica* they are on 31 and 33, while in trapezoides, they are continuous on 31 to 33 inclusive.

Helodrilus caliginosus trapezoides is by far the most abundant and is very widely distributed in the United States. This species seems to be found in all soil types. They are capable of living in very acid and alkaline soils. This will be discussed more fully in another part of the paper.

This species has never been listed for Ohio heretofore, though it occurs nearly everywhere that collections have been made (Fig. 4).

Helodrilus (Allolobophora) **chloroticus** Savigny, 1826:183

Enterion chloroticum E. *virescens* Savigny, 1826:183.
Allolobophora chlorotica Vejdovsky, 1884:60.
Helodrilus (Allolobophora) *chlorotius* Michaelsen, 1900a:486.
Lumbricus riparius Hoffmeister, 1843:189.
Allolobophora riparia Eisen, 1874:46.

Length, 5-7 cm. Somites 80-125. Color more or less greenish. Prostomium epilobic. Setae closely paired. Clitellum on somites 29-37. Tubercula pubertatis consist of three pairs of sucker-like elevations on somites 31, 33, and 35. First dorsal pore on 4/5. Spermiducal pores on 15, between b and c. Oviducal pores on 14, slightly dorsal of b. Spermathecal pores on 8/9-10/11, in line with the dorsal bundles. Septa 6/7-13/14 are moderately thickened; those from 9/10 diminish gradually towards the posterior. Sperm sacs in 9-12. Spermathecae are in 9, 10, and 11, extending freely into the somite cavities with ducts of moderate length.

Helodrilus chloroticus is widely distributed in Europe and various parts of the world. In North America it has been reported from Greenland, North Carolina, Vancouver Island, California, Mexico, Guatemala, District of Columbia, Indiana, and Colorado.

Helodrilus chloroticus has been collected in the following counties in Ohio: Franklin, Delaware, Marion, Hancock, Butler, Wood, and Lucas (Fig. 5).

It has not been listed for Ohio heretofore.

Subgenus **Dendrobaena** Eisen, 1874

The characters for this subgenus are as follows: Setae widely paired or separate. The spermathecal pores on 9/10 and 10/11 in the setae lines of c or d. There are three pairs of sperm sacs in 9, 11, and 12.

Smith (1917) states that some of these characters are combined with others belonging to other subgenera, breaking the dividing line and making the classification difficult. This the writer finds to be true and has followed Smith as to classification.

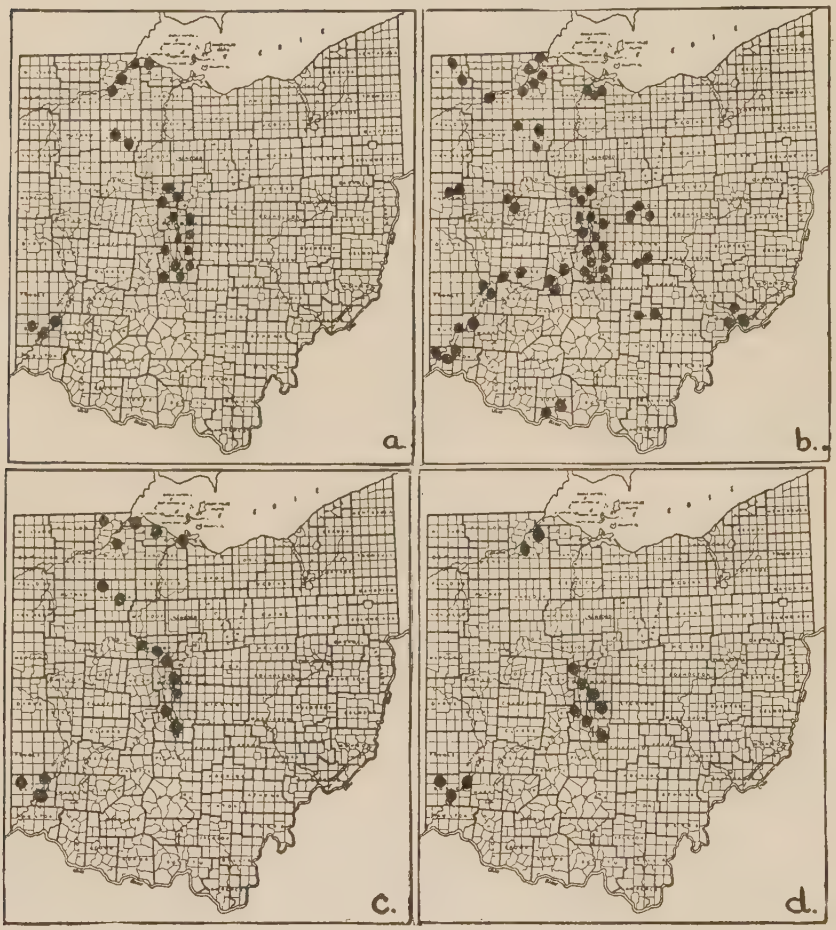


FIGURE 5

Fig. 5—a Helodrilus chloroticus b Helodrilus subrubicundus
c Helodrilus tumidus d Helodrilus hempeli

Helodrilus (Dendrobaena) **subrubicundus** Eisen, 1874:51

Allolobophora subrubicundus Eisen, 1874:51.

Helodrilus (Dendrobaena) *rubidus,* var. *subrubicundus* Michaelsen, 1900a:490.

Helodrilus (Dendrobaena) *subrubicundus* Michaelsen, 1910:52.

Length, 5-8 cm. Somites 80-125. The anterior dorsal surface is of a variable red color. Prostomium epilobic ⅔. Setae widely paired; bc:cd:dd = 2:1:4; cd is a little greater than ab. Clitellum on somites 26-31, and may invade 25 or 32. Tubercula pubertatis on somites 26-30. First dorsal pore on 5/6. Spermiducal pores on 15, between b and c. Oviducal pores on somite 14, slightly dorsal of b. Spermathecal pores on 9/10 and 10/11, in the seta line c. Septa 7/8 and 8/9 moderately thickened, 6/7, 9/10, 13/14 and 14/15 slightly thickened. Sperm sacs in 9, 11, and 12. Spermathecae in 9 and 10, free in somite cavities, with very short ducts which enter the septa near the body wall.

This species is distributed very widely in Europe and various parts of the world. It has been reported in North America from Newfoundland, California, Colorado, Canada (Niagara), and Illinois.

Helodrilus subrubicundus is usually found in wet soil where there is more or less sewage contamination. This species and *H. foetidus* are often found together. It has been collected in Franklin, Delaware, Marion, Knox, Logan, Mercer, Sandusky, Lucas, Wood, Madison, Clark, Butler, Hamilton, Adams, Montgomery, Hocking, Licking, Washington, Williams, and Henry counties (Fig. 5). This species has not been listed for Ohio heretofore.

Subgenus **Bimastus** (H. F. Moore), 1893

In this subgenus the tubercula pubertatis are indistinct or lacking. There are but two pairs of sperm sacs, which are in somites 11 and 12. The spermathecae are not normally developed. The clitellum in most of the species under this subgenus does not extend posterior to 32.

Helodrilus (Bimastus) **tumidus** Eisen 1874

Allolobophora tumida Eisen, 1874a:45.
Allolobophora (Bimastus) *tumida* Michaelsen, 1900:10.
Helodrilus (Bimastus) *tumidus Michaelsen*, 1900a:502.

Length 2-5 cm. Somites 40-60. Color, reddish brown. Prostomium epilobic ¾. Setae closely paired. Clitellum on somites 22-29. Tubercula pubertatis on somites 27 and 28, rather inconspicuous. Spermiducal pores on 15, with small glandular elevations. Oviducal pores on 14, slightly dorsal of b. First dorsal pore is on 5/6. The septa 6/7-9/10 are slightly thickened, 8/9 somewhat thicker, and 13/14 and 14/15 are about the same as 8/9. The longitudinal partitions are about 40 in number. Spermaries and spermiducal funnels are in somites 10 and 11. Sperm sacs are in 11 and 12. Spermathecae are lacking.

This species is found under moss and leaves in damp woods. It has been listed only for Mount Lebanon, New York (New England of Eisen's paper). I do not think that this species is identical with *H. gieseleri hempeli,* as I have collected several worms which

correspond to the description of *Helodrilus tumidus*. I find that they are abundant between decayed leaves. I have collected specimens in the following counties: Franklin, Marion, Delaware, Hancock, Wood, Butler, Ottawa, and Lucas (Fig. 5). This species has not been listed for Ohio heretofore.

Helodrilus (Bimastus) **gieseleri** var. **hempeli** Smith, 1915:551

Helodrilus (Bimastus) *gieseleri* var. *hempeli* Smith, 1915:551.

Length, 4-7 cm. Somites, 100-110. Color of the dorsal half of the body is brown red, while the ventral half lacks pigment. The setae are close, posterior to the clitellum, aa:ab:bc:cd:dd = 20:4:16:3:52. Clitellum is situated on 22-29 and sometimes part of 30. Tubercula pubertatis lacking. First dorsal pore on 5/6. Spermiducal pores on 15, slightly dorsal of b. Oviducal pores on 14, slightly dorsal of b. Septa 6/7, 7/8 and 13/14 slightly thickened. Longitudinal partitions of the calciferous gland about 40 in number. Sperm sacs are in somites 11 and 12. Spermathecae are lacking.

This species has often been collected in decayed leaf material, under logs and rotten wood. They have been collected in Florida (Monticello), Illinois, Kansas, Texas, and Ohio. I have found this species in the following counties: Delaware, Butler, Franklin and Wood (Fig. 5). This species has also been collected in Indiana by the writer. It has not been listed for that state heretofore.

Helodrilus (Bimastus) **parvus**, Eisen, 1874

Allolobophora parva Eisen, 1874a:46.

Allolobophora (Bimastus) *parva* Michaelsen, 1900:10, 14.

Helodrilus (Bimastus) *parvus* Michaelsen, 1900a:502.

Length, 3-4 cm. Somites, 90-110. The color of the anterior dorsal surface is brownish red. Prostomium epilobic $\frac{1}{2}$-$\frac{4}{5}$. Setae closely paired; a little posterior to the clitellum, aa:ab:bc:cd:dd = 18:4:16:3:48. Clitellum on somites 24-30. There are very indefinite ridges (tubercula pubertatis) on somites 25-29, occasionally beginning on 26 or reaching 30. The first dorsal pore on 5/6. The spermiducal pores on 15, between b and c. Oviducal pores on 14, slightly dorsal of b. Septa 7/8 and 8/9 are slightly thickened, others scarcely any. There are about 40 longitudinal partitions of the calciferous gland. The sperm sacs are in 11 and 12. The spermathecae are absent.

Helodrilus parvus has been reported from Guatemala, Mexico, China, Japan, Africa, New York, California, Louisiana, Kansas, and Michigan. The writer has collected *Helodrilus parvus* only in the extreme northwestern part of the state (Williams County) (Fig. 6). Attempts to find it again have failed. It has not been listed for Ohio heretofore.

Helodrilus (Bimastus) **beddardi** (Michaelsen) 1894

Allolobophora beddardi Michaelsen, 1894:182.

Allolobophora (Bimastus) *beddardi* Michaelsen, 1900:10, 13.

Helodrilus (Bimastus) *beddardi* Michaelsen, 1900a:502.

Length, 2-6 cm. Somites, 70-100. The anterior dorsal surface is red. Prostomium, epilobic ½-⅔. Setae closely paired; aa:ab:bc:cd:dd=26:4:20:3:80. Clitellum on somites 24-31, but sometimes it begins on 25, and often invades 32. The tubercula pubertatis, if that is what the ridges represent, are found on 25-30. Smith states that the tubercula pubertatis are indefinite ridges on 24 or 25-30. I have never found any traces of them on somite 25. First dorsal pore on 5/6. Spermiducal pores on 15, between b and c. Oviducal pores on 14, slightly dorsal of b. Septa are all very thin. The longitudinal partitions of the calciferous gland are about 40 in number. Sperm sacs are in 11 and 12. Spermathecae are lacking.

This species has been reported for the Hawaiian Islands, Tibet, Florida, California, Washington, Michigan, Illinois, Montana, but has not been listed for Ohio heretofore. It has been collected in Wood and Lucas counties (Fig. 6).

It was collected in very wet situations, such as in woods, under decaying vegetation, logs and stumps.

This species is closely allied to *H. B. parvus* and at one time there was doubt as to their real distinctness.

Helodrilus (Bimastus) **longicinctus** Smith and Gittins, 1915:548

Length of Ohio specimens, 7-10 cm. Somites 100-130. The anterior dorsal part of the worm is rose red, while the other parts are decidedly lighter in color. Prostomium epilobic ½-⅔. Setae closely paired: aa:ab:bc:cd:dd = 10:1:7¼:4/5:30. There is a slight variation in the position of the setae in some of the worms collected. Clitellum on 23-32 or 24-33 and the ventral edges do not extend further ventrally than b. Tubercula pubertatis entirely lacking. First dorsal pore on 5/6. Spermiducal pores on 15, slightly dorsal of b and surrounded by prominent glandular areas which encroach on 16. Oviducal pores on 14, slightly dorsal of b. Septa 6/7 and 14/15 somewhat thickened and 7/8-13/14 more strongly thickened. There are about 60 longitudinal partitions of the calciferous gland. Sperm sacs in 11 and 12. The spermathecae are lacking.

Smith states that *H. longicinctus* occurs abundantly in the soil of lawns, parks, and near-by woodlands of Urbana, Illinois, and this is the only locality from which it has been reported. It has been collected in Hocking County, Ohio, at Cantwell Cliffs, in a wooded area at the bottom of the gorge where the soil is sandy and wet with abundant leaf material also present (Fig. 6). It is new for Ohio.

Helodrilus (Bimastus) **zeteki** Smith and Gittins, 1915:545

Length 10-12 cm. Color of Ohio specimens is purple brown on the anterior dorsal surface. Somites 110-140. Prostomium epilobic, 1/2-1/3. Setae closely paired, anterior to the clitellum, aa:ab:bc:cd:dd = 6:1:5:1:20; posterior to the clitellum, bc is relatively greater and dd somewhat less. Clitellum on 27-37, and extends ventrally enough to include the ventral setae of 30-36. Tubercula pubertatis entirely lacking. First dorsal pore on 5/6. Spermiducal pores on 15, slightly dorsal of b. Oviducal pores on 14, slightly dorsal of b.

Septa 6/7-12/13 are slightly thickened, those of 13/14 and 14/15 more strongly so. There are about 60-64 partitions of the calciferous gland. Sperm sacs in 11 and 12. Spermathecae lacking.

Smith states that this species has been collected in considerable

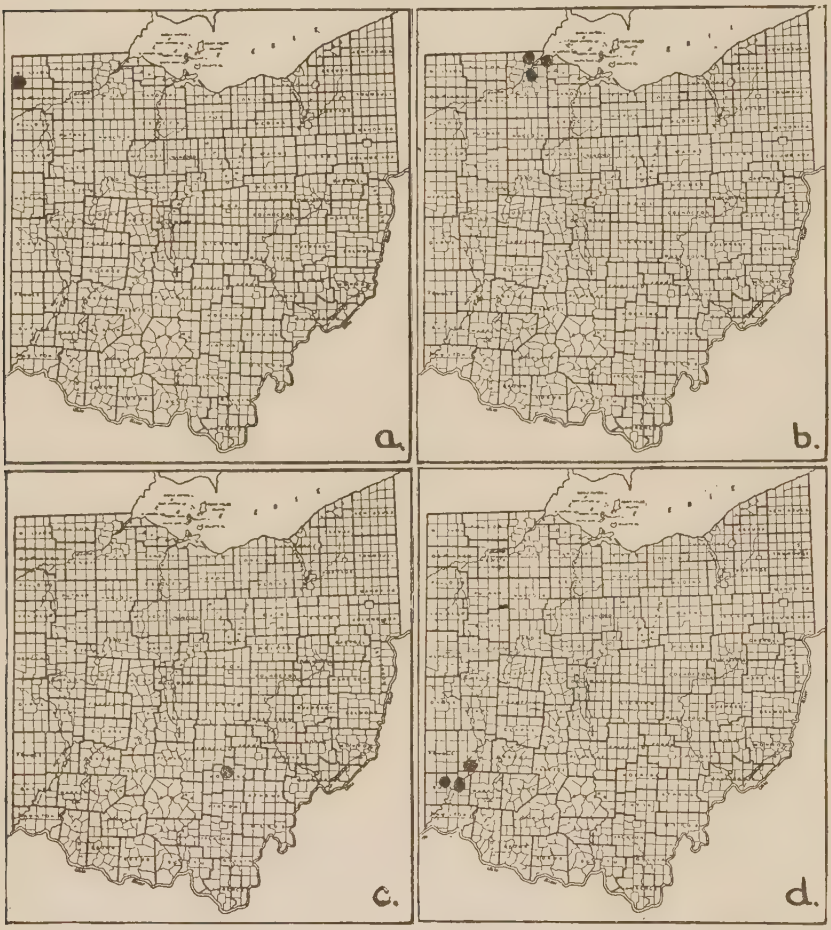


FIGURE 6.

Fig. 6—a Helodrilus parvus b Helodrilus beddardi
c Helodrilus longicinctus d Helodrilus zeteki

numbers in Illinois, Indiana, and Michigan. The counties in which this species was collected in Ohio are Butler and Montgomery, where it is found quite abundantly under decaying logs, leaf material, and bark (Fig. 6). It has not been listed for Ohio heretofore.

Helodrilus (Bimastus) **tenuis** Eisen, 1874

Allolobophora tenuis Eisen, 1874a:44.
Allolobophora constricta Rosa, 1884:38.
Allolobophora (Bimastus) *constricta* Michaelsen, 1900:8.
Helodrilus (Bimastus) *constrictus* Michaelsen, 1900a:503.
Allolobophora norvegica Eisen, 1874:48.
Helodrilus (Bimastus) *tenuis* Smith, 1914:364.

Length, 4-8 cm. Somites 90-100. Color of the anterior dorsal surface is rose-red, the rest of the body a decided pale color. Prostomium epilobic 2/3. Setae widely paired: aa:ab:bc:cd:dd = 12:5:10:7:35 is about the relation slightly posterior to the clitellum. Clitellum is situated on somites 26-31. Smith states that the tubercula pubertatis are indistinct and often lacking; when present usually on 29 and 30, occasionally invading 31. In only one case in Ohio material, the tubercula pubertatis were found to invade 31. The ventral setae of the sixteenth somite are borne on glandular papillae. First dorsal pore on 5/6. Spermiducal pores on somite 15, between b and c, situated on glandular elevations. Oviducal pores on somite 14, slightly dorsal of b. Septa are thickened slightly throughout. There are about 40 longitudinal partitions of the calciferous gland. Sperm sacs in 11 and 12. Spermathecae usually lacking in the typical form, although the writer has collected some specimens with the spermathecae not fully developed.

Helodrilus tenuis has been collected in almost all parts of Europe, Asia, and South America. In North America it has been collected in Mexico, Alaska, Vancouver Island, Canada, California, New York, Illinois, Maine, Indiana, Michigan, Colorado, Washington, Bering Island, and Ohio.

It is most abundantly found under decayed leaf mold, and decayed timber. I have collected this species in the various counties of the State of Ohio: Wood, Lucas, Hancock, Ottawa, Wyandot, Mercer, Franklin, Delaware, Licking, Marion, Knox, Guernsey, Washington, Madison, Clark, Butler, Summit, Hocking, Fairfield, Ashland, and Belmont (Fig. 7). It is probably found in almost all of the counties of Ohio.

Genus **Octolasium** Orley, 1885:13, emended by Rosa, 1893:424

The prostomium of this genus is usually epilobic, but may be tanylobic. The setae are paired, widely paired, or separate. The spermaries and the spermiducal funnels are inclosed in paired sperm vesicles or in narrow chambers.

Octolasium lacteum Orley, 1881

Lumbricus terrestris var. *lacteus* Orley, 1881:584.
Octolasium lacteum Orley, 1885:21.
Octolasium lacteum Michaelsen, 1900a:506.
Allolobophora profuga Rosa, 1884:47.

Length, 5-16 cm. Somites 100-170. A few of the anterior somites are pink in color; the posterior end is pale, while the remainder of the body,

except the clitellum, is blue gray. Prostomium usually epilobic, ½-⅔; occasionall tanylobic. The setae anterior to the clitellum are definitely paired, and ab is less than bc; posterior to the clitellum, the setae are scarcely paired, and ab is equal to or greater than bc; bc is greater than cd, in most cases. Clitellum on somites 30-35. Tubercula pubertatis on 31 to 34. First dorsal pore on 8/9, 9/10, or 10/11. Spermiducal pores on 15, nearer to c than to b. Oviducal pores on 14, slightly dorsal to b. The spermathecal pores on 9/10 and 10/11, in line with c or d. The septa 6/7-8/9 are slightly thickened and 9/10-13/14 are still less thickened. There are about 45 longitudinal partitions of the calciferous gland. The calciferous gland communicates at its anterior end with the esophagus. The spermaries and the spermiducal funnels in 10 and 11, included in sperm vesicles. The sperm sacs are in 9-12; those of 9 and 10 being quite different in form and appearance from those of 11 and 12, which resemble those commonly found in the Lumbricidae. The sperm sacs of 9 and 10 are digitiform and have a definite lumen extending through the greater part of the length.

Octolasium lacteum is abundantly found under decayed logs, leaf mold, compost heaps. They are also found in rich soil. This species is widely distributed in Europe and in various parts of the world. It has been collected in Illinois, California, Mexico, Indiana, Colorado, and Ohio. I have collected it in the following counties in Ohio: Franklin, Marion, Delaware, Butler, Hocking, Madison, Clark, Montgomery, Wood, Lucas, Ottawa, Pickaway, Fairfield, Washington, and Cuyahoga (Fig. 7).

Family SPARGANOPHILIDAE

In the original description of *Sparganophilus* (Benham 1890), this genus was placed in the family Rhinodrilidae. Later it was placed under the family Glossoscolecidae. In 1917 Michaelsen united the families *Glossoscolecidae* and the *Lumbricidae* into the *Lumbricidae* sens lat, and then subdivided the family *Glossoscolecidae* into five sub-families; *Glossoscolecidinae, Sparganophilinae, Microchaetinae, Criodrilinae,* and *Hormogastrinae.* These were given equal rank with the *Lumbricinae* (formerly *Lumbricidae)* in the new family *Lumbricidae* sens lat. According to this classification *Sparganophilus* is the only genus of the sub-family *Sparganophilinae.* Previous to this it was considered the ancestral form of the *Glossoscolecidae.* Michaelsen, in a recent paper considers the *Sparganophilinae* a degenerate descendant of the *Glossoscolecidae.* In a more recent paper Michaelsen (1921) created a super-family *Lumbricina,* under which he places the families *Glossoscolecidae, Sparganophilidae, Microchaetidae, Hormogastridae, Criodrilidae,* and the *Lumbricidae.*

Genus **Sparganophilus** Benham, 1892

Benham Quart. J. Micro. Sci., 34:155.
Eisen Mem. Calif. Ac., 2:5:151, 1896.

The setae are closely paired. Prostomium not marked off from the buccal segment (zygolobic). Nephridiopores in setal line a or ab. The clitellum is

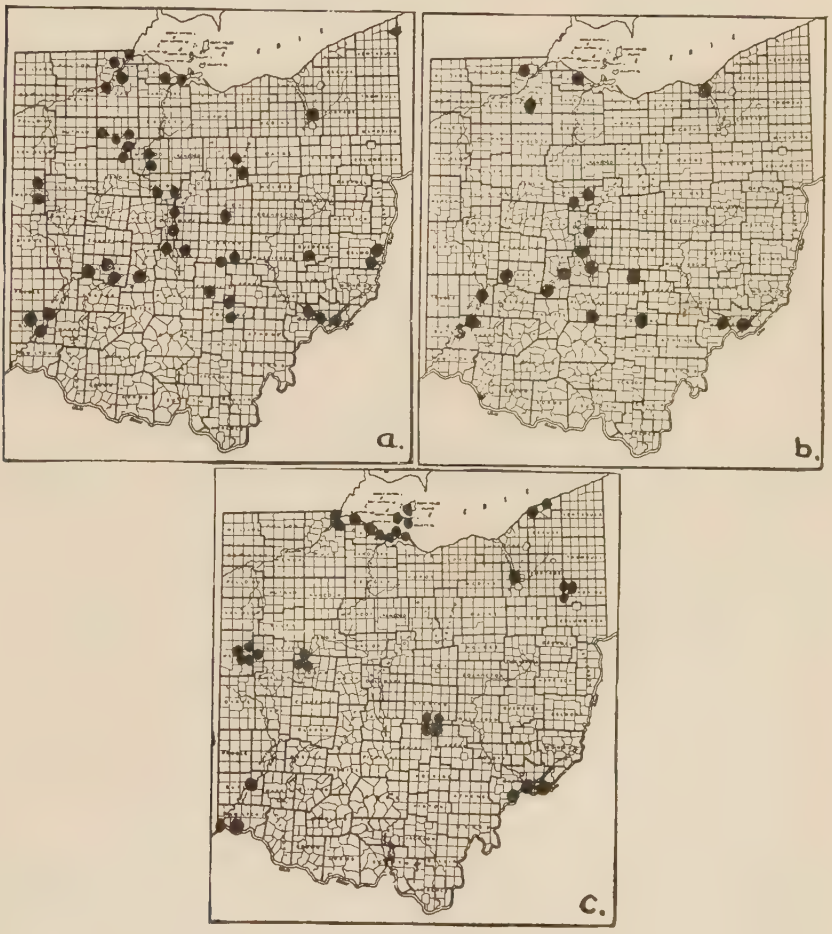


FIGURE 7.

Fig. 7—a Helodrilus tenuis b Octolasium lacteum
c Sparganophilus eiseni

weakly developed ventrally, to some extent accompanied by the protruding pubertatis. The spermiducal pores are on a smooth surface, upon the intersegmental groove 18/19 or in the anterior region of somite 19. The seminal receptacles are single, or several in groups, situated anterior to the testicle somite. The esophagus simple, no gizzard; calciferous gland and the esophageal pouches absent. The last heart in somite 11. There are two pairs of testicles and seminal funnels; two pars of clusterlike seminal pouches in

somites 11 and 12. There are numerous prostate-like glands in several pairs which open out in the ventral part of the clitellum. (Translation from Michaelsen's *Das Tierreich*).

Sparganophilus eiseni Smith, 1895

Length from 15-20 cm. Somites 165-225. Color, pink with blue and green iridescence. Setae c and d are in the dorsal half of the worm. Clitellum on 15-25. Tubercula pubertatis on 17-22. Spermiducal pores on somite 19, the oviducal pores on 14, both rather inconspicuous. Spermathecal pores are ventral to the setae line c, and are in the inter-segmental grooves of 6/7, 7/8 and 8/9. The gizzard and the calciferous glands are absent. Spermathecae are in 7, 8, and 9. Ovaries in somite 13; ovisacs in 14. Spermaries and spermiducal funnels in somites 10 and 11. Sperm sacs are lobed and paired and lie in somites 11 and 12. First typical nephridia are in somites 13 or 15. Accessory reproductive organs are present in some one or more of somites 3 to 10, or are regularly present in 23-26 or adjacent somites.

Eisen (1896) reported the presence of the anterior reproductive (parietal) glands in *Sparganophilus eiseni.* Since these glands were not present in other specimens of Sparganophilus, it was thought that these glands distinguished *Sparganophilus eiseni* from other species. According to Miss Florence S. Hague, in her detailed study of *Sparganophilus eiseni,* she finds that these glands are too variable in their occurrence to be regarded as a basis for separating species. It was also stated previous to her study that *Sparganophilus eiseni* and *Sparganophilus benhami* differed in size; in position of the tubercula pubertatis; anterior nephridia; shape of the spermathecae; lobulation of sperm sacs; and the relative size of the pharyngeal (septal) gland. Miss Hague has shown that there is quite a variation in each of these characters among the specimens of *Sparganophilus eiseni* studied and that there are conditions among some of these specimens which are very similar to the condition described in *Sparganophilus benhami.* Smith also made a detailed study of a specimen identified by Eisen as *Sparganophilus benhami* and came to the conclusion that it revealed nothing which was different from conditions found in *Sparganophilus eiseni.* My observations agree with this conclusion.

Smith states that *Sparganophilus eiseni* is abundant in the mud of the bottom and margins of many rivers and lakes east of the Mississippi River.

It was collected by the writer in the following counties: Lucas, Ottawa, Lake, Mercer, Logan, Butler, Hamilton, Licking, Fairfield, Washington, Summit, and Mahoning (Fig. 7).

Genus **Diplocardia** H. Garman, 1888

Diplocardia (type D. *communis)*, Garman, 1888:47.
Diplocardia (subgenus), Beddard, 1891:270.
Geodrilus (Type G, *singularis)* Ude, 1893: 69.
Acanthodrilus, Beddard, 1895:527.
Aleodrilus, (Type A. keyesi), Eisen, 1896:145.
Diplocardia, Eisen, 1899:161.
Diplocardia, Eisen, 1900:168.

Setae paired, absent from segment 19 on which the male pores are present; spermiducal pores on 18, 20. Clitellum, 13-18. Two pairs of prostate pores on both somites adjacent to the male pores. There are three pairs of sperm pouch pores, the posterior one on the 9th somite. Two muscular crops, mostly in the 5th and 6th, rarely in the 6th and 7th somites; separated, pouch-shaped calciferous glands. Esophageal pouches absent. Two pairs of free testicles and sperm funnels.

Terrestrial and in fresh water. In North America found in Florida, Georgia, North Carolina, Nebraska, Lower California, Mexico, Illinois, and Ohio. The writer lists this genus for Ohio.

Diplocardia communis, Garman, 1888:47

Length 18-30 cm. Number of somites 125-160. Color of the anterior dorsal surface pale flesh. Setae widely separated. Clitellum saddle-shaped, situated on somites 13-18 inclusive. Prostate pores on somites 18 and 20. Spermiducal pores in somites 19 and the spermathecal pores in somites 6/7, 7/8 and 8/9. Sperm sacs in 9 and 12.

This species was the first of the genus to be described. It differs from the others in having a double dorsal blood vessel throughout the entire length of the body. Smith states that this species is abundant in the prairie soils of central Illinois. Nothing more is known of its distribution.

Although it is common locally in Clark, Franklin, and Madison counties (Fig. 8), it has not been listed for the state heretofore.

Diplocardia riparia Smith, 1895

Length 20-27 cm. Somites 135-160. Color of anterior dorsal surface dark brown, much darker than in *D. communis*. Setae in four pairs, wide apart. Clitellum, saddle-shaped, on 12-18, of a dull copper color, usually slightly developed and sometimes absent. Prostate pores on somites 18 and 20. Spermiducal pores on somite 19, near anterior margin of somite. Two pairs of spermathecae, one pair in each somite of 18 and 19, with the external openings at the anterior margins of those somites and in line with the inner rows of setae. Sperm sacs in somites 9 and 12. The ovaries are in somite 13, and the female pores in somite 14. Spermathecal pores on somites 7/8 and 8/9.

Smith, 1915, states that *Diplocardia riparia* is plentiful in the rich soil of the bottom land forests of Illinois. It has been collected in Franklin, Delaware, and Licking counties, always along a stream

or body of water, where the moisture content of the soil is high (Fig. 8). It has not been listed for the state heretofore.

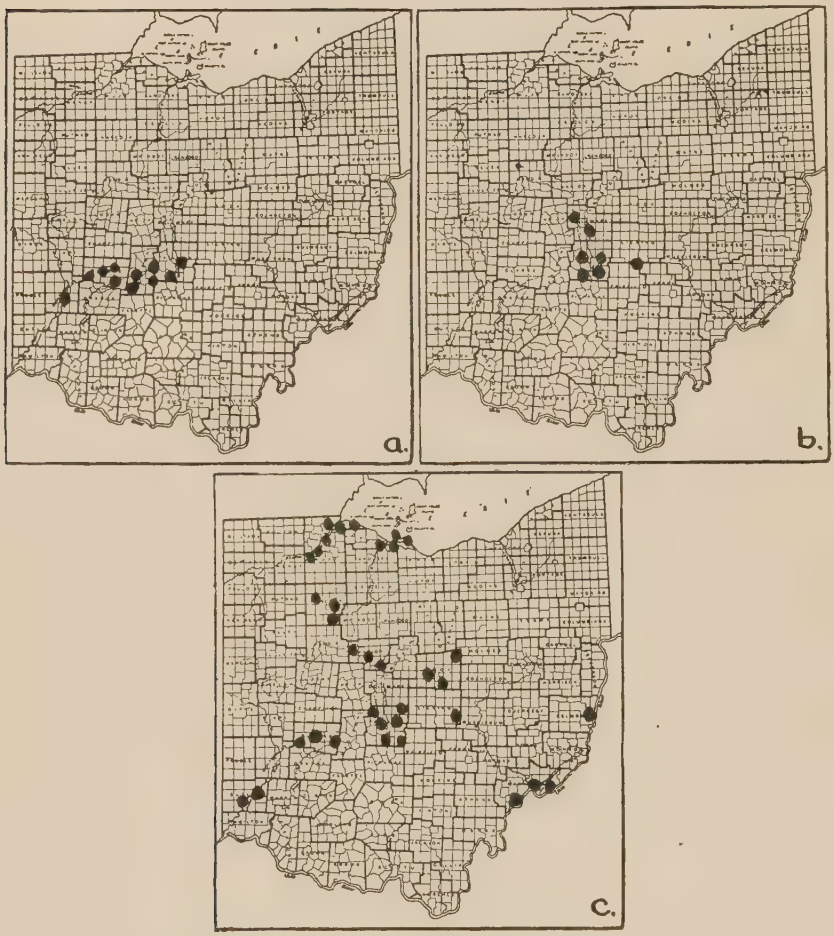


FIGURE 8

Fig. 8—a Diplocardia communis b Diplocardia riparia
c Diplocardia singularis

Diplocardia singularis Ude, 1895:129.

Length 18-30 cm. Number somites 90-120. Anterior dorsal surface flesh color. Setae wide apart. Clitellum on somites 13-18, inclusive, of the cingulum type. Prostate pores on somites 18 and 20. Spermiducal pores on somite 19, and the spermathecal pores on somites 6/7, 7/8, and 8/9. Sperm sacs in somites 9 and 12.

This species is listed as being quite common in the upland regions of central Illinois. It was collected in the following Ohio

counties: Franklin, Marion, Delaware, Knox, Hocking, Washington, Hancock, Wood, Lucas, Ottawa, Butler, Belmont, and Clark (Fig. 8). It occurs in great numbers locally in Ohio, but has never been listed for the state heretofore.

Family HAPLOTAXIDAE

The family Haplotaxidae and the only genus under this family can readily be distinguished by the long and slender form, the great number of somites, the extremely thick cuticle, and the weak longitudinal muscle layer. The setae are simple, and are placed singly in four longitudinal rows, two ventral and two dorsal. The dorsal may sometimes be absent. The convoluted nephridia open to the surface before or behind the setae. The ventral ganglia usually have two swellings in each somite. The sex glands occur in somites 9-12. The seminal receptacles are in somites 6-8.

Genus **Haplotaxis,** Hoffmeister, 1843

Lumbricus (part), Hartmann, 1821:45.
Tubifex (part), Duges, 1837:33.
Haplotaxis (H. menkeana), Hoffmeister, 1843:193.
Phreoryctes (P. menkeanus), Hoffmeister, 1845:40
Georyctes, Schlotthauber, 1860:122.
Nemodrilus (N. filiformis), Claparede, 1862:275.
Lumbricogordius (L. hartmanni), 1874:260.
Limnodrilus (subgenus), Vaillant, 1890:413.
Dichaeta (Type *D. curvisetosa),* Friend, 1896:110.

Ventral and dorsal setae not everywhere equally large. Nephridial pores in the setal line a or ab. The clitellum ring-shaped. There are two pairs of male pores on the 11th and 12th segments; two pairs of female pores on the intersegmental furrows 12/13 and 13/14. There are two or three pairs of sperm pouch pores. Esophagus with glandular and muscular crop. The sperm ducts are short and simple. Two pairs of ovaries and egg funnels in the 12th and 13th segments.

In fresh waters of Europe, North America, and New Zealand. Two species.

Haplotaxis emissarius Forbes, 1890

Phreoryctes emissarius Forbes 1890:477.
Haplotaxis emissarius Smith; 1918:43.

These worms are long, 12-21 cm., and quite slender and threadlike. Somites 400-500. Usually of a pale red color, with an iridescent luster. The dorsal rows of setae are obsolete except on a variable number of the anterior somites. Prostomium not transversely lobed. The ventral setae continue throughout the body, increasing in size backwards, and becoming large, long, and strongly recurved at the tip. At the middle of the worm the setae may extend into the coelom two-thirds the radius of the body. The dorsal setae diminish in size and disappear in the region of about the one-hundredth somite; from there on their occurrence is irregular. Behind the tip of each seta is a

small oval mass of cells resembling a gland and opening to the surface at the margin of the setal sheath. The pharynx is short, thick-walled, with a heavy roughened cuticle. The esophagus extends through one to three. There are three pairs of degenerated organs, which resemble the spermathecae. They are in the anterior part of 7-9 and open in 6/7-8/9 at the level of the lateral line of either side. The gonads are in 10-13.

On two occasions the State Board of Health sent to the Department of Zoology to be classified some of these peculiar, long, and slender worms. They were taken in Franklin County, Truro Township, and collected in well water. Others were sent to the Zoology Department from Sidney, Ohio.

At one time these worms were thought to occur only in Germany. Hoffmeister (Wiegmann's *Archiv f. Naturgesch.)* gave them the generic name *Haplotaxis*. Menke a little later gave them the specific name *menkeanus*. A few years later the generic name of *Haplotaxis* was found to have been used in Botany and it was then changed to the generic name of *Phreoryctes*. Schlotthauber described a new species of the genus *Georyctes lichtensteinii* (Beiti. 3. *Helminthologie*). Beddard (1888) described another new species *Phreoryctes smithii (Annals and Magazine of Natural History)*. With this he emended the genus. This genus was later mentioned in America by Minot in *The Standard Natural History,* 1885. In this article he gives an illustrated account of the genus. Forbes in 1890 described a species which he found in a well at McLean County, Illinois, naming it *Phreoryctes emissarius*.

DISTRIBUTION OF EARTHWORMS ACCORDING TO HYDROGEN-ION CONCENTRATION, ORGANIC CONTENT, AND THE MOISTURE CONTENT OF THE SOIL

Only within the last few years has there been any attempt to associate hydrogen-ion concentration with the distribution of earthworms. Darwin showed that the earthworms play an important part in working over the soil, periodically exposing the organic matter to the surface, exposing to the air, and sifting it so that no stones larger than the particles which they can swallow are left in the material brought up to the surface. In 1921 Arrhenius published a paper in which he tried to show that the animals in the soil "caused pH and soil type." In his experiments he used two different species of earthworms, one being the Javanese earthworm *Perichaeta indica* and the other *Lumbricus terrestris*. In his first experiment he used *Perichaeta indica*. "These were placed in pots containing quantities of garden soil which were treated with sufficient amounts of acid and alkali and water, to give them the proper

alkalinity and acidity." After he had added the desired solution volumes, each soil was mixed thoroughly and the hydrogen-ion concentration "controlled." He then made a count of the living worms present after a period of five days. He found that there were no living worms except in pots with a pH of 6 and 7. In both of these pots they were very active. He next repeated this experiment with *Lumbricus terrestris,* and, receiving the same results, he came to the conclusion that "the life of the earthworm is strongly influenced by the reaction of the soil, so that earthworms can only live in slightly acid or neutral soils." He further stated that "earthworms cannot live in raw humus which has a pH lower than 6, but live and propagate very well at a pH of around 6 and 7."

In 1924 Salisbury showed that just as there is a fairly rapid increase in the organic content in the soil when we pass from subsoil to the surface, so too there is usually a modified rise in the real acidity in the same direction. Salisbury's work dealt mainly with the organic content of worm casts. He showed that the organic content was higher than that of the surface soil. He also showed that earthworms cause considerable change in the reaction of the acid soils, in some cases amounting to as much as 0.75 pH. His table shows that the effect is more marked the more acid the original soil, and that the acidity of the soil is also invariably decreased, while the effect on the alkaline soils may be to diminish the alkalinity.

Recently the experiment which Arrhenius performed was repeated by the writer. Instead of preparing soils by adding acids and alkalies to obtain a definite pH, soils were collected throughout the state, and a series of soils with a pH running from 4.5 to 8.4 were used. Distilled water was added to the soils to give them their proper moisture. In each case about 15 to 20 per cent of moisture was present in the soils. The pH was then retaken, and the soils placed in pyrex beakers, as pyrex does not affect the pH as much as ordinary glass. The earthworms used for this experiment were *Lumbricus terrestris.* In a day or so it was noticed that those earthworms to which the soil was favorable would burrow in the soil, while those to which the soil was unfavorable would stay on top and die. Daily observations were made and after a period of four weeks earthworms were found to be living at a pH as low as 4.5 and as high as 8.4 instead of pH 6 and 7. This species undoubtedly has a wide pH range, as compared to the conclusions of Arrhenius, 1921, in which he state "that earthworms cannot live in a raw humus which has a pH lower than 6, but live and propagate

very well in mild humus soils 6 and 7." There is the possibility that the artificially prepared soils which were used by Arrhenius in his experiments might account for the difference in our conclusions.

Later in making a collection of the earthworms of Ohio, the writer decided to collect and tabulate the various soils in which worms were found. The hydrogen-ion concentration, moisture, and organic content of the soils were taken. A list showing the various places in which I found *Lumbricus terrestris* over the state, as well as other species, will be given. *Lumbricus terrestris* has never been collected by the writer in soils lower than pH of 5.45, nor higher than 8.60. The moisture content of soils collected was as low as 14 per cent and as high as 47 per cent, the organic content as low as 2 per cent and as high as 5 per cent. See Table V. This earthworm was seldom seen in Central Ohio ten years ago. In Columbus, ten years ago, there were only a few places in which Lumbricus could be found. Now it occurs in all parts of the city. It is used quite extensively for fish-bait.

Helodrilus caliginosus trapezoides is the most widely distributed and generally abundant of our Ohio species of earthworms. The writer has made very few collections in which he has not found this species and it has been collected in every county. Often it is found in association with other species such as *Lumbricus rubellus, Lumbricus terrestris, Helodrilus zeteki, Helodrilus roseus, Helodrilus chloroticus, Helodrilus tenuis,* and *Octolasium lacteum.* Soil samples were collected and determined for hydrogen-ion, moisture, and organic content, to determine whether earthworms occur in soils of a pH lower or higher than 6 or 7, and to notice if the moisture or organic content is important to earthworm distribution. Arrhenius states "that the life of the earthworm is very strongly influenced by the reaction of the soil, so that they can live only in slightly acid and neutral soils. That the earthworms cannot live in raw humus which has a pH lower than 6, but live and propagate very well in the mild humus lying around 6 and 7. Mr. Prescott of the Siltan Agricultural Society, Cairo, had the kindness to mention that he never observed earthworms in Egypt either in garden soils or in agricultural land, and according to my observations nearly all good Egyptian soils have a pH above 7.53."

Arrhenius' observations and experiments were different from the writer's in that the distribution of earthworms has a wider range of pH than his conclusions would lead me to infer. From about three hundred soil samples in which I collected *Helodrilus caliginosus trapezoides,* it was found in soils ranging from pH 7.6

to 8.4. More worms were collected at a pH of about 8.0 than at any other. They were also collected in a pH as low as 5.4 and as high as 8.7. The majority of these worms were collected in soil with an organic content of 4 per cent, while the lowest per cent was 1, the highest 5 per cent. More worms were collected in a moisture content of 20 per cent, but they were very abundant in a moisture content ranging from 15 to 30 per cent. The lowest per cent in which they were collected in the field was 10 per cent, while the highest was 50 per cent. Table I shows their distribution as to type of soil, organic content, pH, and moisture.

Helodrilus tetraedrus is widely distributed over the state. It was found, after an analysis of soil samples, that this species has also a wide hydrogen-ion range. It was collected in soils with a pH as low as 6.8 and as high as 8.5. The average moisture percentage was considerably higher than that of *Helodrilus caliginosus trapezoides,* probably due to the fact that *Helodrilus tetraedrus* is usually found along the banks of streams or lakes. The lowest moisture content in which this species was present was 25 per cent, while the highest was 35 per cent. The organic content was never less than 4 per cent and in a great many cases it was about 5 per cent. Table II shows the analysis of some of the various soils in which *Helodrilus tetraedrus* was taken.

In collecting the Diplocardia in various parts of the state, the writer also made an analysis of the soils. It was found that the Diplocardia occur in a pH as low as 5.50 and as high as 8.60. They were abundant in soils of a pH of 8.0, with an extremely high moisture content. The lowest percentage of moisture was 25 per cent while the highest was 37.4 per cent. The organic content was as low as 4 per cent and in a good many examples it exceeded 5 per cent. Table III shows its distribution.

Soils were also collected in which no worms were found. The pH moisture and organic content was also taken. Table IV. In most cases the organic content was extremely low or nil, and in others it was about 5 per cent. As an example, in Delaware County, soil was found along the bank of Alum Creek whose organic content was nil, the moisture content 9 per cent and the pH was 4.25. No worms were found. The soil was very shaly. Probably no worms occur there because of the fact that all four factors—type of soil, organic content, moisture and pH—were in all cases extreme. In Hancock County soil samples were collected in which the moisture content was extremely high, 66 per cent. The organic content was also high, the pH as low as 5.4. This soil was a typical muck

TABLE I

DISTRIBUTION OF *Helodrilus caliginosus trapezoides*, AS TO pH, ORGANIC CONTENT, MOISTURE, TYPE OF SOIL, AND PLACES FOUND

County	Type of Soil	Per cent Organic Content	pH	Per cent Moisture
Belmont	Westmoreland series, Dekalb silt.	2	5.45	15
Delaware	Volusia Silt and Clay Loam.....	5	5.45	38.2
Delaware	Volusia Silt and Clay Loam.....	5	5.50	22.4
Belmont	Westmoreland Series, Dekalb Silt	3½	5.95	29
Guernsey	Dekalb and Meigs Series.....	4	6.20	12
Knox	Wooster Silt Loam.....	4	6.35	27
Knox	Wooster Silt Loam.....	5	6.35	13
Belmont	Westmoreland Silt and Clay Loam	4	6.55	30
Delaware	Volusia Silt & Clay, Decayed Leaf	3	6.30	24.5
Delaware	Volusia Silt and Sand Gravel....	5	6.70	11.3
Franklin	Miami Silt and Clay Loam.....	3	6.73	21
Marion	Clyde Clay and Miami Silt Loam.	4	6.80	20
Licking	Volusia Silt and Loam.....	3½	6.80	26
Lucas	Clyde Clay and Dunkirk Sand....	5	6.80	35
Franklin	Volusia Silt and Clay Loam.....	4½	6.92	16.5
Franklin	Volusia Silt and Clay Loam.....	5	6.93	16
Delaware	Decayed Leaf Material.....	5	6.95	2.3
Marion	Clyde Clay and Miami Silt Loam.	4	6.95	20
Guernsey	Dekalb and Meigs Series.....	2½	6.95	24
Hancock	Miami Silt Loam and Clay.....	5	7.0	32.5
Hancock	Miami Silt Loam and Clay.....	5	7.20	51
Delaware	Volusia Silt.....	5	7.05	29.9
Delaware	Volusia Silt and Clay Loam.....	1	7.20	12.6
Marion	Clyde Clay and Miami Silt Loam.	5	7.20	25
Wood	Clyde Clay and Dunkirk.....	4½	7.20	10.5
Delaware	Volusia Silt and Clay Loam.....	5	7.30	35.5
Marion	Clyde Clay and Miami Silt Loam.	5	7.30	18
Guernsey	Dekalb Silt Loam.....	3	7.20	25
Muskingum	Dekalb Silt Loam.....	3½	7.40	23
Wyandot	Miami Silt and Clay Loam.....	5	7.40	32
Delaware	Miami Silt and Clay Loam.....	5	7.40	25.9
Licking	Volusia Silt Clay Loam.....	2	7.40	16
Franklin	Decayed Log Material.....	4	7.42	10
Delaware	Miami Silt and Clay Loam.....	5	7.55	30.3
Knox	Wooster Silt Loam, Sand & Gravel	4	7.50	20
Delaware	Volusia Silt and Clay Loam.....	2	7.55	24
Franklin	Volusia Loam and Sandy Loam..	4	7.58	15
Lucas	Clyde Clay and Dunkirk Sand....	4	7.55	15.15
Franklin	Volusia Silt Loam and Clay.....	4	7.65	16
Lucas	Clyde Clay and Dunkirk Sand....	5	7.65	23
Hancock	Miami Silt and Clay.....	1	7.70	24
Knox	Wooster Silt and Clay Loam.....	5	7.70	28.5
Madison	Miami Silt and Clyde Clay.....	1	7.70	22.7
Butler	Miami Silt and Fox Series.....	5	7.70	24
Warren	Fox Series & Miami Silt & Clay..	2	7.80	20
Montgomery	Miami Bellefontaine Series.....	3	7.80	16
Licking	Volusia Silt and Clay Loam.....	5	7.80	31
Muskingum	Dekalb Silt Loam.....	3½	7.80	23
Wyandot	Miami Silt and Clyde Loam.....	4	7.90	31
Wyandot	Miami Silt and Clyde Loam.....	4½	7.90	24.5
Wyandot	Miami Silt and Clyde Loam.....	1	7.90	17
Delaware	Miami Silt and Clay Loam.....	5	7.90	31.5
Miami	Fox Series	4	7.90	22
Franklin	Volusia Silt and Clay Loam.....	4	7.86	20

soil. In only one case, the writer found earthworms and this was in sod. The pH of all the soil samples was determined by the quinhydrone method.

TABLE I *(Continued)*

DISTRIBUTION OF *Helodrilus caliginosus trapezoides*, AS TO pH, ORGANIC CONTENT, MOISTURE, TYPE OF SOIL, AND PLACES FOUND

County	Type of Soil	Per cent Organic Content	pH	Per cent Moisture
Franklin	Very Sandy Loam	5	7.97	20
Franklin	Miami Silt and Clay Loam	5	8.0	29
Lucas	Clyde Clay and Dunkirk Sand	4	8.0	30
Butler	Miami Silt and Fox Series	4	8.0	37
Clark	Miami Silt Loam	3	8.05	17.5
Clark	Miami Silt Loam	5	8.05	37.4
Licking	Volusia Silt and Clay Loam	5	8.05	41
Licking	Volusia Silt and Clay Loam	4	8.05	23
Muskingum	Dekalb Silt Loam	3	8.05	23
Muskingum	Dekalb Silt Loam	4	8.05	33
Wood	Clyde Clay and Dunkirk Sand	4	8.05	23
Wood	Clyde Clay and Dunkirk Sand	5	8.05	24
Hancock	Miami Silt Loam and Clay	4	8.05	35
Clark	Miami Silt Loam	5	8.30	32
Madison	Miami Silt and Clyde Loam	3½	8.30	20.5
Franklin	Sandy Clay and Chenango Sand	2	8.39	20
Madison	Miami Silt and Clyde Loam	4	8.40	23
Licking	Volusia Silt and Clay Loam	5	8.40	23
Miami	Fox Series	2	8.40	18
Clark	Miami Silt Loam	4	8.40	24.4
Clark	Miami Silt Loam	3½	8.40	15.1
Montgomery	Miami Bellefontaine Series	4	8.40	20
Butler	Miami Silt and Fox Series	2	8.40	21
Butler	Miami Silt and Fox Series	4	8.60	17
Montgomery	Miami Bellefontaine Series	3½	8.70	20
Montgomery	Miami Bellefontaine Series	3	8.70	18

TABLE II

HELODRILUS TETRAEDRUS

County	pH	Per cent Moisture	Organic Content
Lucas	6.8	35	5 +
Lucas	7.6	25	5
Wyandot	7.9	31	4
Butler	7.9	25	5 +
Wood	8.05	23	4
Wood	8.05	25	4
Hancock	8.05	35	4
Hancock	8.05	28	5++
Madison	8.4	25	5
Madison	6.5	35	4
Butler	8.5	35	5 +

TABLE III

DIPLOCARDIA

County	pH	Per cent Moisture	Organic Content
Delaware	5.50	24	5 +
Delaware	6.5	30	4 +
Butler	7.45	35	5 +
Madison	8.05	37.4	5
Butler	8.07	30	5
Madison	8.2	24	4
Wyandot	8.25	23.5	3½
Clark	8.25	20.6	4
Clark	8.30	25	4
Wyandot	8.40	24	4
Licking	8.40	23	5 +
Butler	8.40	35	5 +
Licking	8.60	25	4

TABLE IV

EARTHWORMS ABSENT

County	pH	Per cent Moisture	Organic Content
Delaware	4.25	9	nil.
Delaware	5.0	4.1	2%
Hancock	5.4	50	5%
Hancock	5.86	66	5%
Belmont	8.6	10	nil.
Licking	8.7	12	1%
Franklin	5.0	4	nil.
Warren	8.4	6	nil.

TABLE V

Lumbricus terrestris ACCORDING TO HYDROGEN-ION, MOISTURE, AND ORGANIC CONTENT

County	Hydrogen-ion	Per cent Organic content	Per cent Moisture
Delaware	5.45	5	38.2
Knox	6.30	4	25
Delaware	7.30	5	47
Delaware	7.50	4	20
Delaware	7.55	3	19
Delaware	7.60	4	32
Marion	7.80	3	20
Marion	7.90	2	15
Warren	7.97	3	20
Franklin	8.00	2	22
Franklin	8.00	4	30
Franklin	8.10	3	25
Franklin	8.12	4	20
Franklin	8.20	4	23
Lucas	8.25	4	25
Wyandot	8.25	3.5	15
Muskingum	8.25	4	25
Belmont	8.25	3	20.6
Belmont	8.25	4	35.7
Belmont	8.30	4	22
Belmont	8.35	5	37
Butler	8.40	3½	15
Clark	8.40	4	20
Butler	8.50	5	17
Butler	8.60	2	20
Montgomery	8.60	3	22
Montgomery	8.60	4	18

CONCLUSIONS

1. Earthworms studied in this research will live and are found abundantly in soils below and above the hydrogen-ion concentrations of 6 and 7.
2. They have an extreme range pH 4.5 to 8.7 in natural soils of Ohio.
3. A single species, *Helodrilus caliginosus trapezoides*, is found in soils of pH as low as 4.5 and as high as 8.7. There is also a great variation of organic content and moisture.
4. The optimum pH at which most *H.c. trapezoides* are found in Ohio is 8.0.
5. *Lumbricus terrestris* is found in natural soils which are of much higher pH than those mentioned by Arrhenius. They were almost always collected in soils above pH 5.45 and were found in soils with a pH of 8.6 and 8.7.
6. The optimum pH at which most of the worms were collected was around 8.25. *Lumbricus terrestris*, as well as other species, will live in a much wider range than that mentioned by Arrhenius. They were found to live in soils as low as pH 4.5 and as high as 8.4 under laboratory conditions. The natural soils of Ohio were used.
7. There is a possibility that the artificially prepared soils, in which various acids and alkalies were added to give them their proper acidity and alkalinity, would give different results than the natural soils which were collected throughout the state. No acids or alkalies were added by the writer.
8. Arrhenius and Salisbury state that earthworms will be found more abundantly at the neutral point. From the results of the various soils collected throughout the state, it was found that they were more abundant at a pH of 8.00.
9. The moisture and organic content seem to play an important part in their distribution. Most worms were found in soils of a moisture content from 12 to 35 percent; the organic content being from 4 to 5 per cent.
10. In extreme conditions of pH, moisture, organic content, and type of soil, worms were scarce or not found. Where moisture, organic content, and pH were very low, worms were usually not present. Where moisture, organic content, and pH were high, worms would be scarce or not present.

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BIOGRAPHY

Henry William Olson was born in Canton, Ohio, October 19, 1902. He received practically all of his secondary school education in the public schools of Columbus, Ohio. The last half of his senior year was spent in Westerville high school, from which he graduated in 1919. His undergraduate years were spent at Otterbein College. He received the degree of Bachelor of Arts in 1923 and Bachelor of Science in 1924. While an undergraduate he was an assistant in the department of zoology. In the year of 1924-1925 he had charge of the biology department at Findlay College, Findlay, Ohio. His graduate training was received from The Ohio State University, from which he received the degree of Master of Arts in June, 1926. He attended the Franz Theodore Stone Laboratory, Put-in-Bay, Ohio, during the summers of 1926 and 1927. During the years of 1926, 1927 and 1928 he completed the requirements for the degree of Doctor of Philosophy.